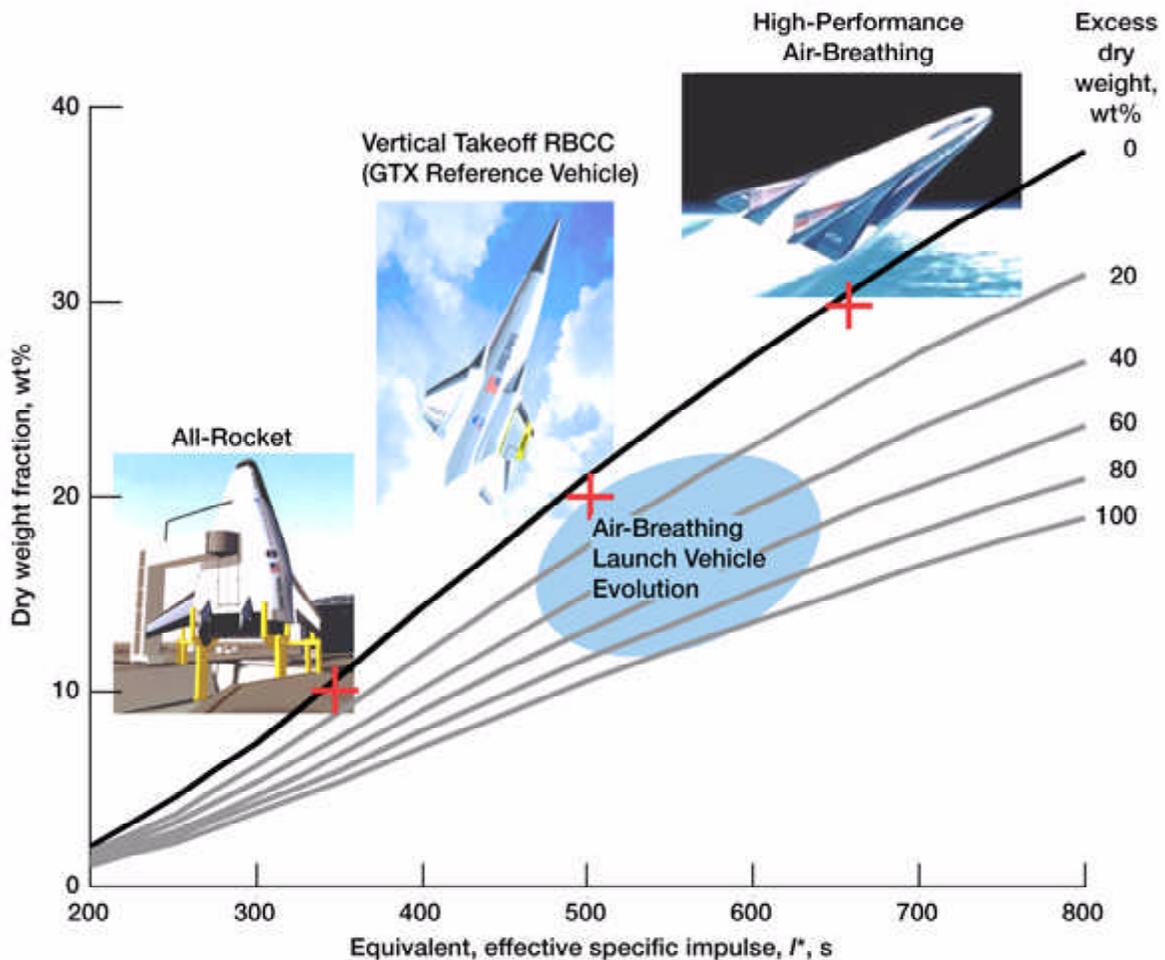


# Air-Breathing Launch Vehicle Technology Being Developed

Of the technical factors that would contribute to lowering the cost of space access, reusability has high potential. The primary objective of the GTX program (ref. 1) is to determine whether or not air-breathing propulsion can enable reusable single-stage-to-orbit (SSTO) operations. The approach is based on maturation of a reference vehicle design with focus on the integration and flight-weight construction of its air-breathing rocket-based combined-cycle (RBCC) propulsion system.

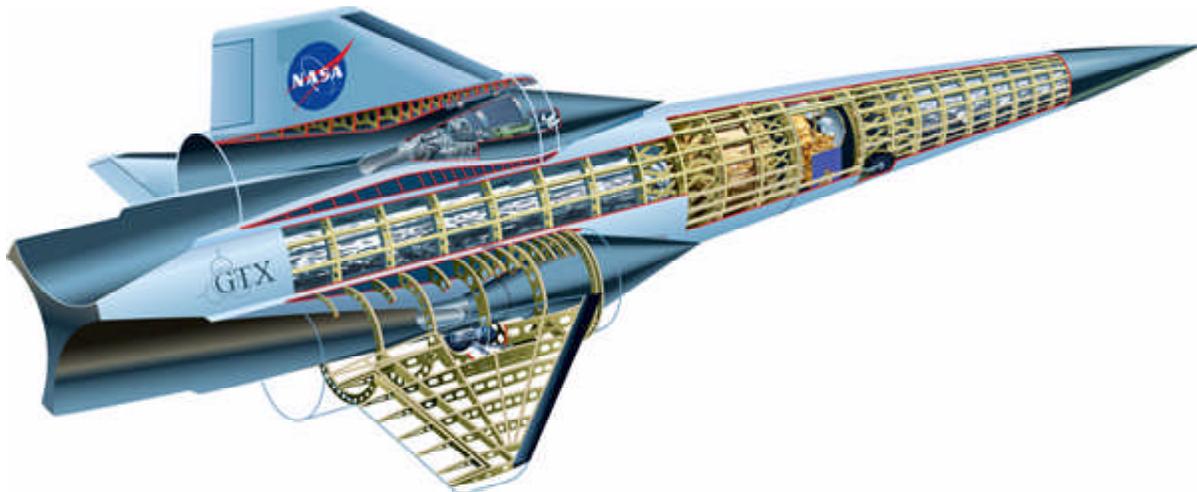


*Effect of aeropropulsion efficiency on the SSTO dry weight fraction for a 220-nmi flight from a 28.5° easterly launch into a circular orbit (RBCC, rocket-based combined cycle).*

Long description of figure 1 Graph of dry weight fraction versus equivalent, effective specific impulse for excess dry weights of 0, 20, 40, 60, 80, and 100 wt%; several aircraft milestones are shown on the chart: all-rocket, vertical takeoff RBCC (GTX Reference Vehicle), air-breathing launch vehicle evolution, and high-performance air-breathing.

The preceding graph shows the effect of the equivalent, effective specific impulse  $I^*$ , a

system-level efficiency parameter, on the dry weight fraction required for SSTO. Three classes of SSTO systems are shown. SSTO rockets such as the VentureStar (ref. 2) concept are limited to the lower  $I^*$  range and rely on advancements in structural and material technologies that were to be provided by NASA's recently terminated X-33 (ref. 3) program. Increasing  $I^*$  appears to make SSTO vehicles more practical by increasing the allowable dry weight fraction. However, the weight of the air-breathing propulsion system, the effects of atmospheric flight on the configuration, and any added complexity must be considered before a benefit can be claimed. An upper limit to  $I^*$  is represented by the "high-performance" air-breathers, of which the National Aerospace Plane (ref. 4) is a good example. High-specific-impulse low-speed systems and acceleration to high scramjet Mach numbers result in a dry weight budget of 30 wt%. These configurations are biased more toward aeropropulsion than structural efficiency, however, and they grow to an impractical scale at closure, especially if existing runways must be used. The optimum  $I^*$  for a reusable SSTO vehicle may be between these two extremes. The vertically launched GTX reference vehicle, shown in the following figure, represents this "middle-class"  $I^*$  range, achievable with a relatively simple combined-cycle propulsion system with rocketlike performance at low speed, a moderate maximum air-breathing Mach number, and a structurally efficient configuration. The GTX program will determine whether or not this approach will result in a reusable SSTO vehicle at a practical scale. Increased excess dry weight resulting from future improvements could be used to increase payload, reduce vehicle size, and increase reliability.



*GTX reference vehicle.*

Validation of system performance will ultimately require the construction and operation of a series of demonstration vehicles (ref. 5). To this end, researchers at the NASA Glenn Research Center have identified a comprehensive suite of propulsion component and system test rigs for developing and validating the design. Reference 1 provides an overview and the status of each test rig. Notable accomplishments in fiscal year 2002 include (1) the completion of inlet testing in Glenn's 1- by 1-Foot Supersonic Wind Tunnel and (2) the first phase of direct-connect flow path testing in Glenn's Engine Components Research Laboratory. In addition, finite-element modeling and optimization of the propulsion system and vehicle were also completed in fiscal year 2002 (ref. 6).

Research on the lightweight, regeneratively cooled panels required for constructing the air-breathing flow path was initiated (ref. 7). Computational fluid dynamics (CFD) has been used extensively throughout the program for aerodynamic design, pretest prediction, and extrapolation of test results to reference vehicle scale and flight conditions. Recent work includes three-dimensional calculations of the various fuel injection and mixing processes resident in the multimode flow path (ref. 8).

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